NBSIR 78-1414 (CPSC)

# An Evaluation of Safety Standards for Gasoline and Kerosene Cans

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Final Report

Prepared for
**Bureau of Engineering Sciences**
**Consumer Product Safety Commission**

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**NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director***

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of the standards to the functional failure modes showed very little applicability to Child Access Prevention and Containment, Active; some indirect applicability to Dispensing; Containment, Passive; and Barrier; good direct applicability to Handling and Stability; Identification; Storage Control and Structural Integrity.

It is concluded that Containment, Active failures cannot be directly addressed in a standard because of the extremely rigorous structural requirements that such standards would impose. It is further concluded that there is an urgent need to develop methods and standards to child-proof containers, to improve user control of dispensing liquid from the container, and to increase the isolation of liquid in the container from external ignition sources. However, it is also concluded that the standards reviewed provide a sound technical guide for the handling and stability, structural integrity and proper identification of containers for flammable and combustible fluids as well as preventing unintentional release of liquids from the container openings.

# AN EVALUATION OF SAFETY STANDARDS FOR GASOLINE AND KEROSENE CANS

## 1. INTRODUCTION

Accidents which involve flammable liquids are primarily related to the nature of the liquids. These liquids are both flammable, toxic and hazardous as liquids and as fumes independent of the action of the user. The accidents, however, are also related to the interaction between the use of the liquids and the characteristics of the containers in which they are stored, transported and handled and from which they are dispensed. The nature of this interaction is critical to the development of safety standards for gasoline and kerosene containers.

The purpose of this study is to evaluate existing product safety standards for gasoline and kerosene containers and to recommend provisions in areas not covered adequately by these standards. The analysis is limited to container function as revealed by the use of the containers. Two previous studies at NBS, Pezoldt (3) and Tyrrell (4), have provided quantitative analyses of container involvement in gasoline accidents. These studies are not duplicated here although some overlap in scope and content is unavoidable because of similarities of data source and interpretation. The analysis is further restricted to the technical applicability of the standard. It is not concerned with the feasibility of applying these standards, or suggested standards, to containers designed for home use since feasibility goes beyond technical applicability. The technical applicability of the standards can be evaluated by a comparison of the provisions of the standard with the product performance safety requirements. The feasibility of applying the standards to the product is dependent upon such factors as cost and maintainability which cannot be evaluated on the basis of the data available for this study.

This study is primarily a description of what users do with containers of flammable liquid when using the liquid and how the containers function or fail to function when so used. This description is the basis for the evaluation of existing safety standards and recommendations for further standards.

Although the analysis in this study is primarily non-quantitative some quantitative description of the data base is presented to facilitate understanding of the limitations imposed by the data on the findings of

the study. This quantitative description is valid only for the data base, i.e., the NEISS data, FFACT reports and IDIR's actually used, and must not be presumed to be statistically descriptive of the real world of flammable fluid accidents.

It should be noted that the data base includes accidents with flammable and combustible liquids other than gasoline and kerosene. It is recognized that the behavior of these liquids may not be identical with gasoline and kerosene in ignition characteristics. However, it is felt that there is sufficient similarity so that container functioning can be generalized from their behavior where they are involved in the accidents included in the data base.

The study is not directly a study of gasoline or kerosene containers per se since only 15 percent of the containers involved in the accidents can be identified as gasoline or kerosene containers designed as such. However, the uses to which all types of containers were put, and the results of using them, are analyzed to reveal what functions a container should perform and what functional failures should be addressed by a safety standard.

## 2. METHOD

The data base for the present study consisted of the following:

a. National Electronic Surveillance System (NEISS) data--the NEISS data were for FY 74, 75 and 76 and were tabulated by products (Gasoline, Kerosene and Gasoline Cans), age of victim, and type of injury.
b. In-Depth Investigative Reports (IDIR)--there were 134 IDIR's covering container related flammable and combustible liquid accidents for 1974, 1975, 1976.
c. Flammable Fabric Accident and Case Testing System (FFACTS) narrative reports--there were 115 reports covering container related flammable and combustible liquid accidents for 1966 through 1973. FFACTS data collection was terminated in 1974.

Each of these data sources has a bias toward certain types of accident injuries. The NEISS data and, to a slightly less extent the IDIR's, both derive from emergency rooms rather than from burn centers or morgues. These data thus somewhat understate the frequency and severity

of burn accidents, especially for small children for whom a given burn area comprises a larger proportion of total body surface area than for adults. The FFACT reports, on the other hand, are restricted to burn accidents and thus do not reflect other types of accidents, e.g., those involving ingestion or aspiration of liquids.

This data bias does not seriously interfere with the analysis of container failure for the purpose of this study, although a larger number of ingestion and aspiration cases might have been useful in studying the role of container design in these types of accidents. What is more of a handicap in the analysis of container problems is that the data sources used emphasize the flammable liquid aspect of the accidents rather than the container aspects. The containers are infrequently described in detail. Hence, the role of the containers in the accidents must often be inferred, especially as to structural integrity and details of configuration. Also, there are no narrative accounts of cuts, abrasions, etc. from direct contact with the container.

In view of the above limitations of the data base the identification of container involvement from the IDIR's and FFACT reports probably neglects some container failure modes which result in accidents in real life. This is especially true of container failures due to structural defect and degradation, e.g., seam failure, corrosion, punctures. Furthermore, it should not be assumed that the container involvement modes identified in this study occur with the same relative frequency in real life as they do in the IDIR's and FFACT reports.

The literature search on flammable fluid containers resulted in only four references of any value to the present study. Three of these references, Pezoldt (3), Tyrrell (4) and Halsey, Kirstein and Snyder (2) originated at NBS. The other reference, Greene and Cinibulk (1), suggested the functional failure mode approach which is used in this study.

The analysis of the data proceeded as follows: summary of NEISS data, summary of IDIR and FFACT reports, analytic coding, code sequencing, functional failure mode analysis, functional failure tabulation, standards review, standards evaluation.

The NEISS data were tabulated by product (gasoline, kerosene, gasoline container), for victim age and type of injury. This summary was intended to describe the general data base for the study. The description is more applicable to the IDIR data than to the FFACT data.

Each IDIR and FFACT report was summarized on a 4" X 6" card. This card was the immediate reference data source for all further analysis. Figure 1 is an example of such a report summary card. The summary included the report number, identification of the liquid, identification of the container, the age of the operator, the operation performed with the container, the involvement of the container in the accident, the involvement of the liquid in the accident, and the involvement of the victim in the accident. The report number is an identifying number written on the copy of the IDIR or FFACT report used in the study and served to retrieve the report for further reference if the summary card was not sufficient in some detail. The age of the operator, i.e., the user or manipulator of the container, was only noted for children 5 years or younger. This age limit is arbitrary and is intended primarily to identify a need for child proofing of containers. The Operation entry states what was done with or to the container. The C (container) involvement entry states the role of the container as a factor in the accident, e.g., that it spilled gas. The L (liquid) involvement entry states the role of the liquid in the accident, e.g., that it ignited in the can. The victim involvement entry completes the accident picture by stating how the accident impacted on the victim, e.g., that he was burned by ignition of gasoline on his shirt. The victim, in most cases, is the operator but his role as a victim is of no essential interest in the analysis except as it is relevant to the performance of the operator, container or liquid.

No: 149

Liquid: Gasoline    Container(s): Glass Jar    0 Age:

Operation: Poured gas on barbecue coals.
Threw burning jar away.

C involvement: Gas ignited in jar from flashback.
Gas spilled when jar was thrown.

L involvement: Ignited in jar and burned when
splashed from thrown jar.

Victim involvement: Burned by burning gasoline
splashed from jar.

FIGURE 1. Report Summary Card

The information from the summary card was coded for type of container, user operation, fire action mode, container involvement mode, and injury mode. The coding was recorded on the back of the summary card. This code is presented in Appendix 1. The sample summary shown by Figure 1 was coded as follows:

1L - Open top glass or ceramic container
2a - Pour or spray liquid
2d - Throw or kick away container
3a - Liquid interface
3d - Liquid or fumes to fire
3h - Fire transition to container
4b - Fire burned in container
4e - Ignited liquid splashed or spilled
5c - Victim injured by burning fluid.

After all summaries had been coded the event codes were placed in their sequence of occurrence for each accident. This sequence was recorded on the back of each summary card. The accident event code sequence for the accident summarized in Figure 1 is:

$$2a \rightarrow \begin{matrix} 3a \\ | \\ 3d \end{matrix} \rightarrow 3h \rightarrow 4b \rightarrow 2d \rightarrow 4e \rightarrow 5c$$

In the sequence the arrows (→) indicate a sequence of events and the vertical line (|) represents events occurring more or less simultaneously. The sequence shown above can be read as follows: the operator poured the liquid (2a), there was a liquid/fire interface (3a) in which the liquid went to the fire (3d), the fire flashed back to the container (3h), the fire burned in the container (4b), the operator threw the container (2d), flaming flquid splashed from the container (4e) and the operator (victim) was burned by the flaming liquid (5c).

The functional failure mode analysis was carried out on the event code sequences to reveal the ways in which the container did not function as an operationally safe container. The functional failure mode analysis is an adaptation of the Failure Mode and Effect Analysis (FMEA) approach to equipment safety assessment. The FMEA attempts to document potential failure modes of equipment and to determine the effects of each failure mode on equipment safety. The FMEA procedure, according to Greene and Cinibulk (1), Page 5, assumes that the equipment is capable of performing within specification requirements and that no false or erroneous action is initiated by the operator.

Obviously, these assumptions are not met by the equipment (containers) and the operators referred to in the IDIR's and FFACT reports. That is, most of the containers conformed to no standard or specification relevant to flammable or combustible liquids and the operators used both the containers and the liquids in a variety of inappropriate ways. A strict FMEA approach is thus not appropriate here. However, the present data analysis indicates certain functions which containers should perform to reduce hazards in the use and misuse of flammable and combustible liquids. The analysis also reveals the effects of functional failure. These functions are as follows:

A. Child Access Prevention (CAP) - Prevention of access to flammable or combustible liquids by a person 5 years of age or younger.

B. Dispensing (D) - Control of the transition of liquid to a selected destination.

C. Containment, Passive (CP) - Prevention of the unintended release of liquid or fumes.

D. Barrier (B) - Prevention of ignition of fluid within a container.

E. Containment, Active (CA) - Confinement of fire, flaming fluid or explosion within a container.

F. Handling and Stability (H-S) - Positioning, holding and carrying control of the container.

G. Identification (I) - Representation of container contents as flammable, combustible, explosive, or toxic.

H. Storage Control (SC) - Provision of a safe and secure environment, including the control and release of vapor build-up, within the container as relatively long term holding facility.

I. Structural Integrity (SI) - Preservation of materials, configuration and security of container and attachments.

Each of the accident sequences was analyzed into failures of these functions, i.e. functional failure modes, and these functional failure modes were noted on the summary cards. The functional failure modes, in the accident summarized in Figure 1 are Barrier (B) and Containment,

Active (CA), i.e., there was a flash-back (3h) to the container which caught fire and spilled flaming gasoline (4e) when it was kicked or thrown.

From the summary cards the functional failure modes were tabulated as "subsequences" involving that particular failure. For example, the accident sequence illustrated in Figure 1, breaks down into subsequence 2a→3h for the Barrier functional failure and subsequence 3h→4b→2d→4e for the Containment, Active functional failure. The subsequences overlap in the interests of giving a complete context for the functional failures. The fire action mode codes 3a (|) 3d are eliminated since they add no significant information to the functional failure context. The functional failure mode subsequences were tabulated for all accidents.

Two of the most comprehensive standards of specific applicability to flammable fluid containers are UL 30, Standard for Safety, Metal Safety Cans, Underwriters Laboratory, October 4, 1974, and PS 61-74, Voluntary Product Standard, Plastic Containers (Jerry Cans) for Petroleum Products, American National Standards MH 17.1-1974, November 21, 1974. UL 30 has also been adopted as ANSI Z218.1, 1971. Also, the Factory Mutual Research Safety Container Standard and the RR-S-30E Federal Specification for Safety Can, Spring Closing Type, contain specific provisions which are of special interest to this analysis although they generally parallel UL 30 for purpose of this report. In addition, the Flammable and Combustible Liquids Code, NFPA No. 30-1976 gives certain basic definitions for flammable and combustible liquids and types of container.

The provisions of the standards and specifications noted above were evaluated as to their applicability to the functional failure sequences. This evaluation was carried out with the assistance of Mr. Emil Braun of the Fire Safety Engineering Division, Institute of Applied Technology, National Bureau of Standards. The relevant provisions of these standards are presented in Appendix 2. The evaluation of these standards were also the point of departure for recommendations for further standard coverage.

Appendix 3 consists of scenarios for each of the functional failure modes. These scenarios are presented to provide a more complete picture of the accident events since the failure mode subsequences presented in Tables III through XVIII are necessarily somewhat fragmentary.

## 3. RESULTS

The type of injury distribution for the NEISS data is shown in Table I. This data base is sampled more intensively by the IDIR's than it is by the FFACT reports. While only 32 percent of the accidents tabulated in Table I involved thermal burn injuries, 80 percent of the combined IDIR and FFACT reports involved thermal burn injuries. This can be interpreted to mean that, for the sample of reports analyzed in the present study, the thermal burn understatement of the IDIR data base is compensated for by the thermal burn overstatement of the FFACT reports. This does not necessarily indicate that the accident report data base for this study is representative of flammable fluid container involvement in real life accidents, even for type of accident. It does, however, indicate that the accident report data base includes an important segment of possible accidents and can be used as a basis for at least some standard evaluation. For example, while the proportion of Dispensing failure modes vs the proportion of Handling and Stability failure modes identified in the data base may not be reflected in the real world of accidents, it is a reasonable assumption that both of these types of accident events do occur.

There is, however, one major point of similarity between the NEISS data in Table I and the combined data from the IDIR's and FFACT reports: 86 percent of children under five years of age in the NEISS data and 86 percent of the children five years of age and under in the combined IDIR and FFACT data were victims of flammable fluid ingestion. This is probably a slight overstatement for the IDIR-FFACT data since victims were not counted in this study unless they were also operators, i.e., a number of small child burn victims were not counted whereas all small child ingestion victims were counted. In both sets of data the proportion of ingestion victims drops off sharply after the five year old group. Although quantitative results must be treated very cautiously in this report, it seems reasonable to say that ingestion is the flammable fluid hazard with which young children are most frequently involved and is primarily a young child problem.

Table II presents the functional failure mode distribution by type of container for the IDIR's and FFACT reports. Cases involving operators five years of age or younger were tabulated only for Child Access Prevention and any other functional failure modes for these 51 cases are not included elsewhere in the tabulations. This does

not result in a major understatement for any of the other functional failure modes except Identification, for which the tabulation does not include 19 cases of misidentification included in the cases tabulated as Child Access Prevention failures. Structural failure modes could not be frequently identified in the accident reports. Only three cases of Structural Integrity and two cases of Storage Control failure were directly identified. However, as noted before, neither the FFACT reports nor the IDIR's were container oriented and most of the containers used, e.g., open top deep or shallow containers, were more configurationally than structurally hazardous as flammable liquid receptacles. Thus, the data source was not adequate for identification of structural defects in containers. However, Table II can and does illustrate the presence of "operational" failures, i.e., Dispensing; Containment, Passive; Barrier; and Containment, Active, across all types of containers, including those identified as "standard". While the format of Table II does not directly show cross relationships between functional failure modes, certain associations were found in the data base. For example, a Barrier failure mode was usually associated with a Containment, Active failure and about two thirds of the Handling and Stability failures were associated with Containment, Passive failures. These associations are rather obvious. A Containment, Active function does not usually become relevant unless a Barrier function fails. Also, a Handling and Stability function failure, e.g., a dropped container, is conducive to a Containment, Passive function failure, e.g., spillage. By contrast, a Dispensing function failure usually occurs without any obvious relationship to other failure modes. It is not, by definition, a Containment, Passive function, does not usually lead to a container fire and cannot usually be identified from the accident report as being due to a Handling and Stability failure or a Structural Integrity failure although both of them may actually have been involved.

Tables III through XVIII present the subsequences of events within which the functional failure modes were identified from the IDIR's and FFACT reports. Each table presents a variation of a functional failure mode. The first column shows the subsequence codes which outline the failure mode, the next column describes the events coded in the subsequence and the last column shows the number of cases in which this subsequence was identified. The last column serves to identify points for discussion but is not a statement of the frequency of occurrence of these events in real life accidents.

The recording and analysis of accident reports after the event is not a highly valid way of determining what actually occurred in accidents. However, for present purposes, the subsequences may be regarded as credible in that such combinations of events do occur. Therefore, the material presented in Tables III through XVIII can be used as a basis for a realistic discussion of the adequacy of safety standards.

Tables III and IV present functional failure mode subsequences for the Child Access Prevention function for ingestion and personal contact and burn events, respectively. The predominant ingestion method employed (32 cases) was drinking directly from the container in which the child found the liquid. In 15 of these 32 cases, there is reason to believe that the child misidentified the container as one containing a normally potable liquid. In the burn cases, the child directly ignited the fluid in the container, poured the liquid and ignited it or poured the liquid near an ignition source. The basic preventive measure for all variations of the Child Access Prevention failure mode is child proofing of all containers containing flammable liquids. Identification of such containers is always desirable but is not a sufficient preventive measure, in itself, where the small child is involved.

Table V presents functional failure mode subsequences for the Dispensing function in which liquid was splashed or spilled on either or both the person or the area. In none of these cases was the liquid ignited at the time of spillage. In 41 of the cases there was a misdirection of pouring. In four cases siphoning was involved. The basic remedial approach to all such problems would seem to be to improve spout design to increase control of pouring and to eliminate the need for siphoning.

Tables VI, VII, VIII and IX present functional failure mode subsequences for the Containment, Passive function in which unignited liquid or fumes are splashed or spilled on the person (Table VI), the area (Table VII), on both person and area (Table VIII), or "other" (Table IX). No one or more predominant subsequences were found for any variation on the Containment, Passive failure mode. The containers were jerked when the operator was startled, dropped, upset, thrown, kicked, washed in and transported. The basic remedy to prevent this failure mode would seem to be a container design and construction that would prevent any release of liquid (including by leakage) except while the operator was deliberately activating such a release, i.e., a "dead man control" provision. Even such design

and construction would not always terminate release of liquid if a startle reaction occurred while the operator was activating release.

Tables X and XI present functional failure mode subsequences for the Barrier function in which fire transitions to the container (Table X) and in which the liquid is directly ignited in the container (Table XI). There are two dominant patterns in Table X, one in which a flashback occurs while pouring liquid on a fire and the other in which a container releases liquid or fumes to a general area in which an ignition source, such as a pilot light, is located and a flashback to the container occurs. In direct ignition of fluid in a container (Table XI) the usual pattern of events is for a fire source, for example, a spark, to directly contact the liquid or fumes in the container. Both varieties of Barrier mode failure might be prevented by a filter or valve in the spout of the container.

Tables XII, XIII, and XIV present functional failure mode subsequences for the Containment, Active function in which the container releases ignited fuel (Table XII), fails to contain an explosion within the container (Table XIII) or fails to contain a fire within the container (Table XIV). The containment of ignited fuel, provided no explosion occurs, might be adressed by the same design and construction standards as for the Containment, Passive function. Containment of fire is a more rigorous requirement, even if no explosion takes place. The containment of an explosion is probably not a reasonable requirement to impose upon container design and structure and, therefore, should not be incorporated in a standard. At a recent 1977 Engineering Foundation Conference on Product Safety, Franklin Pierce College, New Hampshire, there was discussed* a container design consisting of a coil of perforated metal sheets inside a container. This design was presented as a measure to limit fire action within a container and prevent an explosion from developing. However, this device has not been further reported upon. Probably the most, and possibly only, feasible approach to reducing or eliminating Containment, Active function failures is to enhance the operation of the Barrier function.

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*Personal communication, Dr. H.P. Van Cott, Chief, Human Factors Section, Product Systems Analysis Division, Center for Consumer Product Technology, National Bureau of Standards, Washington, D.C. 20234

Table IV presents functional failure mode subsequences for the Handling and Stability function. The containers were knocked over or dropped during pouring or transport or by being bumped into while not in use. The frequency of dropping a container can be reduced by handle design and placement. The knock over problem is a matter of stability design, probably to a large extent configurational. The enhancement of the Containment, Passive function would, of course, reduce the spillage problem from Handling and Stability related accidents.

Table XVI presents functional failure mode subsequences for the Identification function. As noted before, most of Identification problems are associated with liquid ingestion by small children. Table XVI pertains only to older persons. None of the cases in Table XVI involved ingestion. Since the IDIR's and FFACT reports for adults analyzed for the present study are usually for cases in which the operator presumably knew what the liquid was and what he wanted to use it for, one would expect to find relatively few cases of misidentification of the liquid. Nevertheless, clear identification of flammable fluid containers is an obvious safety requirement.

Table XVII presents functional failure mode subsequences for the Storage Control function. These failures can be expected to be reported relatively infrequently in personal injury accident reports since there is relatively little direct personal contact with a container in storage. Storage accidents would tend to be reflected in property damage reports in which personal injury, if any, would tend to be attributed to products other than flammable liquids or containers. The remedy for storage control failure probably lies in container structural and design requirements. It should be noted that some advocates of plastic jerry cans claim that expansion of the plastic can, along with expansion of the liquid contained therein, tends to reduce the chance of container rupture when the temperature of the storage area rises.

Table XVIII presents functional failure mode subsequences for Structural Integrity. In one case a handle fitting allowed leakage, in another case a glass container broke when dropped and in the third case a plastic container melted or burned. As noted before, the IDIR's and FFACT reports are not container oriented and thus do not identify many container failures. Also, in many of the cases analyzed, the accident was primarily related to the configuration of the container involved rather than to its structural defects.

The applicability of the provisions of the UL 30, Metal Safety Can, the PS 6174, Plastic Jerry Can, and the Factory Mutual Safety Containers Standard, and the RR-S-30F Safety Cans Specification to the functional failure modes is summarized in Table XIX. Table XIX is based on Table I, Appendix 2, but the reader should go to the standards themselves for detailed information on specific paragraphs.

Neither UL 30 or PS 6174 has any specific provisions directly or indirectly related to Child Access Prevention. The color and identification provisions of the Federal Hazardous Substances Act may help in teaching a small child what to avoid but they may also make the container more attractive to the child.

The UL 30 standard has spout provisions which probably make pouring stream control more effective for the Dispensing function. The PS 6174 standard has only a general requirement for a spout. The provisions in UL 30, Factory Mutual, and RR-S-30F for Automatic Valve Closure with manual valve opening probably would enhance Dispensing control.

The Containment, Passive function is covered in UL 30 by provisions for containment capacity, valve action and spout leakage. These same provisions are generally in PS 6174 with the exception of any reference to valve action. Structural integrity provisions in both standards are generally applicable to Containment, Passive. The automatic closing valves specified in the UL 30 and Factory Mutual Standards and the RR-S-30F Specification seem to be an approach to a "dead man control" of liquid release through the spout.

There is no specific provision for a Barrier function in either UL 30 or PS 6174. However, it is the opinion of Mr. Emil Braun, Fire Safety Engineering Division, National Bureau of Standards, that the screens or strainers specified in UL 30, paragraphs 12.1 and 12.2, might be adapted as a flashback barrier or a barrier to direct ignition of the interior of the container via the spout. This is probably the intent of the Flame Arrester provision and Fire Exposure test in both RR-S-30F and the Factory Mutual Standard.

. There are no provisions in these standards directly applicable to the Containment, Active function. General structural integrity provisions are somewhat relevant and the effective containment of unignited liquid, i.e.,

Containment, Passive, might also somewhat restrict the release of burning fluid. However, it is probably unrealistic to impose strict standards on containment of fire or burning fluid within a container or to require any containment of an explosion within a container, since such standards would require a greater structural and material strength than would be feasible in portable containers.

Handling and Stability are considered in the standards as different topics. Handling is covered by the UL 30 in terms of placement and configuration of handles to enhance security in carrying the containers and to provide a top and bottom container grip placement for control in manipulating the container. PS 6174 specifies only that a handle shall be provided. The UL 30 handle requirements would seem to reduce the number of incidents from dropped containers. They would also facilitate control of pouring and thus reduce Dispensing functional failures.

Stability, in both UL 30 and PS 6174 is considered as static stability on an inclined plane, of 30 and 20 degrees, respectively. UL 30 also specifies a design for stability in which the diameter of the base of the can shall not be less than 85 percent of the height of the body of the can. These provisions are directly applicable to a static test of stability in which a container is passively placed on a sloping surface. They may not, however, give full consideration to a more dynamic type of stability in which a container is kicked or knocked over to an angle and is subsequently required to fall back on its base. This might be a more severe test of stability than a static incline test, especially if there was liquid "slosh" within the container. The Factory Mutual Standard and the RR-S-30F Specification provide for tilting the can to 30° and requiring it to fall back to an upright position. This test would seem to be more applicable to dynamic stability.

Identification is not touched upon in UL 30. PL 6174 refers to the Federal Hazardous Substances Act. This referral seems adequate as a specification for identification of flammability and toxicity. In fact, a survey of gasoline containers for sale in drug stores, hardware stores, farm supply stores, and elsewhere shows that these containers are generally well identified for their use.

The Storage Control function is generally covered by the Structural Integrity provisions of both UL 30 and PS 6174. In fact, these standards are largely structural

standards. Both cover materials, coating, leak proofing, and an extensive program of structural testing. In addition, PL 6174 deals with melting, brittleness and flammability requirements.

Halsey, Kirstein and Snyder (2) have reviewed the provisions on handling, stability and structural integrity of the standards cited in this report and have performed tests on several containers. Their primary objective was to determine if these standards could be applied to containers for home use. Their conclusions, as stated in their concluding remarks, are quoted below:

> "The purpose of this study was to determine the feasibility of transferring the technology involved in voluntary standards for safety cans to standards for flammable liquid containers for home use. In general, the results of this study on the mechanical tests for stability, leakage, and handle strength indicate that reasonable performance standards for these characteristics can be developed for flammable liquid containers for home use. It remains, of course, for CPSC to establish appropriate pass-fail criteria for the tests.
>
> The results of the pour spout strength tests did not appear to apply directly to containers for home use unless it is deemed necessary or desirable to require that these containers be equipped with valves similar to those used on safety cans. On the other hand, the results of these tests and the associated inverted can leakage tests did accent the need for leak-proof caps and extension spouts. Leak-proof caps and extension spouts are important not only because of liquid leakage in an inverted or upset position, but also because of the possibility of vapor leakage in the upright position and liquid leakage from the cap or extension spout while decanting.
>
> The referenced voluntary standards and specifications [1, 2, 3, and 4] provide additional considerations which may be necessary to produce a meaningful standard for flammable liquid containers for home use. Further studies along these lines could address features such as air vent openings, pressure relief valves, flame

arresting screens, protective coatings, material properties, capacity, fire exposure, color, and markings."

## 4. CONCLUSIONS AND RECOMMENDATIONS

The analysis of the IDIR's and FFACT reports which form the data base for this study has led to the identification of nine major functional failure modes of flammable fluid containers. These modes are failures in the following functions with the associated consequences:

1. Child Access Prevention. A failure results in ingestion of flammable liquid and burn accidents by small children.

2. Dispensing. A failure leads to lack of control of pouring or other transfer of liquid from a container.

3. Containment, Passive. A failure leads to leakage or spillage of unignited liquid on the person or in an area.

4. Barrier. A failure leads to ignition of liquid within a container.

5. Containment, Active. A failure leads to spillage of burning liquid, exposure to a container fire or exposure to an explosion in the container.

6. Handling and Stability. A failure leads to lack of control, dropping or upsetting a container.

7. Identification. A failure leads to treating a flammable liquid as a safe liquid.

8. Storage Control. A failure leads to a flammable fluid accident during relatively passive storage.

9. Structural Integrity. A failure leads to breakdown of a container as a handling or storage device.

An analysis of the applicability of the provisions of the UL 30 Metal Safety Can, the PL 6174 Plastic Jerry Can and the Factory Mutual Safety Container Standards,

and the RR-S-30F Federal Specification on safety cans to these functional failure modes leads to the following conclusions:

1. The standards have no applicability to Child Access Prevention.

2. The standards have some applicability to Dispensing, primarily in the provisions for spout and valve design, operation and structure.

3. The Structural Integrity and valve provisions of the standards are a possible approach to the Containment, Passive function, especially if automatic valve action results in a "dead man control" of liquid release through the spout.

4. The screening and valve provisions of the UL 30 standards suggests a possible line of improvement of Barrier functions, as also do the flame arrester provisions of RR-S-30F and the Factory Mutual Standard.

5. It is not realistic to directly address the Containment, Active function in a standard since this would involve unrealistic material and structural requirements.

6. The handle design and placement provisions of UL 30 seem fairly adequate for setting requirements for container manipulation and transport. However, the stability requirements of the standards may not adequately address dynamic instability of containers, although a tilt test of stability, as in the Factory Mutual Standard, may be considered a dynamic test.

7. The reference in PL 6174 to the provisions of the Federal Hazardous Substances Act seem to adequately address the Identification function. However, this reference should be incorporated in UL 30.

The analysis of the accident data and the evaluation of the standards for containers for flammable and combustible liquids suggests that there is an urgent need to develop methods and standards for child proofing these containers, making the containers more ignition proof and giving the user of the container control over the transition of the liquid from container to objective. Present standards

seem to be generally adequate for container handling and stability and structural integrity and to be specifically applicable to prevention of unintentional release of container contents.

## 5. TABLES

This section contains all tables referred to elsewhere in this report, except for the Standards Summary table in Appendix 2. The tables are made available in this way for reader convenience and to avoid disrupting the text format of the main body of the report.

TABLE I

GASOLINE AND KEROSENE CAN

NEISS FY 1974, 1975, 1976 ACCIDENT DATA DISTRIBUTION

| Diagnosis | Product | Age (Yrs.) <5 | 5-9 | 10-14 | 15-19 | 20-24 | 25-34 | 35-44 | 45-54 | 55-64 | >64 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Burns - Not Specified | Gas | 2 | 2 | 3 | 8 | 4 | 8 | 4 | 5 | 0 | 2 | 38 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| Burns - Chemical | Gas | 25 | 26 | 38 | 53 | 47 | 43 | 48 | 21 | 12 | 8 | 321 |
| | Ker. | 1 | 2 | 3 | 2 | 3 | 4 | 1 | 2 | 3 | 0 | 21 |
| | Gas Can | 0 | 2 | 1 | 4 | 3 | 3 | 1 | 0 | 1 | 1 | 16 |
| Burns - Scalds | Gas | 1 | 0 | 5 | 3 | 2 | 3 | 2 | 0 | 1 | 0 | 17 |
| | Ker. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 |
| | Gas Can | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Burns - Thermal | Gas | 21 | 77 | 147 | 115 | 102 | 143 | 80 | 54 | 32 | 22 | 793 |
| | Ker. | 2 | 2 | 6 | 8 | 3 | 5 | 3 | 1 | 3 | 1 | 34 |
| | Gas Can | 0 | 4 | 5 | 5 | 3 | 3 | 2 | 1 | 1 | 1 | 25 |
| Poisoning | Gas | 441 | 78 | 102 | 119 | 99 | 62 | 14 | 12 | 6 | 2 | 935 |
| | Ker. | 185 | 4 | 0 | 3 | 4 | 2 | 1 | 2 | 0 | 0 | 201 |
| | Gas Can | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| Ingested - Foreign | Gas | 6 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 11 |
| | Ker. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Gas Can | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aspirated - Foreign | Gas | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE I CONTINUED

| Diagnosis | Product | <5 | 5-9 | 10-14 | 15-19 | 20-24 | 25-34 | 35-44 | 45-54 | 55-64 | >64 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dermatitis | Gas | 22 | 8 | 6 | 15 | 20 | 14 | 7 | 6 | 1 | 2 | 101 |
| | Ker. | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| | Gas Can | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Anoxia | Gas | 5 | 2 | 7 | 8 | 4 | 2 | 1 | 1 | 1 | 2 | 33 |
| | Ker. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Gas Can | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 |
| Laceration/ Puncture | Gas | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 5 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 6 | 0 | 5 | 1 | 0 | 2 | 2 | 1 | 0 | 1 | 18 |
| Contusion/ Abrasion | Gas | 0 | 1 | 1 | 3 | 4 | 2 | 2 | 0 | 0 | 0 | 13 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 4 |
| Hematoma | Gas | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Fracture | Gas | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Strain or Sprain | Gas | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 4 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 4 |

| Diagnosis | Product | <5 | 5-9 | 10-14 | 15-19 | 20-24 | 25-34 | 35-44 | 45-54 | 55-64 | >64 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foreign Body | Gas | 3 | 1 | 3 | 9 | 4 | 5 | 2 | 2 | 1 | 0 | 30 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Internal Organ | Gas | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| | Ker. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Gas Can | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | Gas | 528 | 196 | 313 | 335 | 290 | 288 | 163 | 101 | 55 | 38 | 2307 |
| | Ker. | 192 | 9 | 9 | 13 | 12 | 11 | 5 | 6 | 6 | 1 | 264 |
| | Gas Can | 9 | 7 | 15 | 13 | 9 | 10 | 10 | 2 | 3 | 3 | 81 |
| | | | | | | | | | | | | 2652 |

TABLE II

TYPE OF CONTAINER vs FUNCTIONAL FAILURE MODE ACCIDENT DISTRIBUTION

| Type of Container | | Functional Failure Mode: Child Access Prev. | Dispensing | Containment Passive | Barrier | Containment Active | Handling and Stability | Identification | Storage Control | Structural Integrity | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard Gas./Kerosene | | 9 | 10 | 8 | 19 | 18 | 1 | 0 | 1 | 0 | 66 |
| Spout Can | Metal | 2 | 3 | 1 | 11 | 12 | 1 | 1 | 0 | 1 | 32 |
| | Plastic | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 1 | 7 |
| | Unknown | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| Small mouth Jar or Can | Metal | 3 | 4 | 5 | 8 | 8 | 5 | 0 | 0 | 1 | 34 |
| | Glass | 5 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 7 |
| | Plastic, Cardboard | 12 | 5 | 5 | 9 | 10 | 4 | 0 | 1 | 0 | 46 |
| | Unknown | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Bottle | | 4 | 0 | 2 | 5 | 5 | 1 | 0 | 0 | 0 | 17 |
| Open Top - Deep | Metal | 7 | 6 | 17 | 25 | 27 | 6 | 0 | 0 | 0 | 88 |
| | Glass, Ceramic | 4 | 4 | 7 | 10 | 12 | 5 | 0 | 0 | 0 | 42 |
| | Plastic, Cardboard | 4 | 5 | 9 | 8 | 11 | 1 | 2 | 0 | 0 | 40 |
| | Unknown | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 5 |
| Open Top - Shallow | Metal | 0 | 0 | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 10 |
| | Unknown | 0 | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 8 |
| Unknown | | 1 | 6 | 8 | 9 | 12 | 0 | 0 | 0 | 0 | 36 |
| Total | | 51* | 45 | 69 | 114 | 124 | 30 | 3* | 2 | 3 | 441 |

*Child Access Prevention includes 19 cases of misidentification

## TABLE III

### FUNCTIONAL FAILURE MODE SUBSEQUENCE--CHILD ACCESS PREVENTION

### INGESTION (2e) and PERSONAL CONTACT (2g)

| Subsequence | Description | No. Cases |
|---|---|---|
| 4g→2e3 | Liquid access, transferred liquid from one container to another and ingested liquid. | 1 |
| 4g→2e2 | Liquid access, ingested liquid from container | 17 |
| 4g→2i→2e1 | Liquid access, upset container, ingested spilled liquid | 2 |
| 2e2<br>4g→ \|<br>2g | Liquid access, ingested liquid from container and spilled on person | 1 |
| 4g<br>\|→2e2<br>2k | Liquid access with misidentification, ingested liquid from container | 15 |
| 4g<br>\|→2e3<br>2k | Liquid access with misidentification, transferred liquid from one container to another and ingested liquid | 2 |
| 4g<br>\|→2e4→2e2<br>2k | Liquid access with misidentification, opened container and ingested liquid from container | 2 |
| 4g→2g | Liquid access, spilled liquid on person | 4 |

## TABLE IV

## FUNCTIONAL FAILURE MODE SUBSEQUENCE--CHILD ACCESS PREVENTION

### BURN EVENTS

| Subsequence | Description | No. Cases |
|---|---|---|
| 4g→2b→3j→4b | Liquid access, ignited liquid, direct ignition container, fire burned in container | 1 |
| 4g→2i→4d→3i | Liquid access, upset or dropped container, released liquid or fumes in area, direct ignition of person | 1 |
| 4g→2a→3i | liquid access, poured liquid, direct ignition of person | 1 |
| 4g→2i→ 4d / 4c →3e | Liquid access, upset or dropped container, released liquid/ fumes on self and in area, liquid exploded in place | 1 |
| 4g→2a→4c→2b→3g | Liquid access, poured liquid, spilled liquid on person, ignited liquid, fire transitioned to person | 1 |
| 4g→2a→2b→3f→ | Liquid access, poured liquid, ignited liquid, liquid burned in place | 1 |
| 4g→2i→4d→3f | Liquid access, upset or dropped container, liquid/fumes released in area, liquid burned in place | 1 |

TABLE V

FUNCTIONAL FAILURE MODE SUBSEQUENCE--DISPENSING

SPILL, SPLASH, LIQUID, FUMES, PREIGNITION--PERSON (4c), Area (4d)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2a→4c | Poured liquid, spill liquid on person | 25 |
| 2a→4d | Poured liquid, spill liquid in area | 14 |
| 2a→4c / 4d | Poured liquid, spill liquid on person and in area | 1 |
| 2a→2g→4d | Poured liquid, handle liquid, spill liquid in area | 1 |
| 4g→2h→2e | Transferred liquid by siphon, ingest liquid | 2 |
| 4g→2h→4d | Transferred liquid by siphon, spill liquid/fumes in area | 2 |

TABLE VI

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, PASSIVE

SPLASH, SPILL, LIQUID, PREIGNITION, PERSON (4c)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2a→3f→2c→4c | Poured liquid, liquid ignited and burned in place, startled, spilled liquid on person | 1 |
| 2a→2c→4c→3i | Poured liquid, startled, spilled liquid on person, direct person ignition | 1 |
| 2a→2c→4c→3h | Poured liquid, startled, spilled liquid on person, fire transitioned to container | 1 |
| 2e→4c→3f | Dropped or upset container, liquid spilled on person, liquid ignited and burned in place | 1 |
| 2i→4c→3g | Dropped or upset container, liquid spilled on person, fire transitioned to person | 1 |
| 2i→4c→3i | Dropped or upset container, liquid spilled on person, direct personal ignition | 1 |
| 2i→4c→2b→3i | Upset or dropped container, liquid spilled on person, ignited liquid, direct person ignition | 3 |
| 2g→4c→2b→3j | Handled liquid, liquid spilled on person, ignited liquid, direct container ignition | 1 |

TABLE VII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, PASSIVE

SPLASH, SPILL, LIQUID, FUMES, PREIGNITION, AREA (4d)

| Subsequence | Description | No. Cases |
|---|---|---|
| 4d→3h | Release of liquid or fumes in area, fire transition to container | 1 |
| 4d→2b→3h | Release of liquid or fumes in area, ignited liquid or fumes, fire transitioned to container | 2 |
| 4d→3f | Release of liquid or fumes in area, burned in place | 1 |
| 2a→4d→2b→3h | Poured liquid, liquid or fumes released in area, ignited liquid or fumes, fire transitioned to container | 1 |
| 2a→4d→3h | Poured liquid, liquid or fumes released in area, fire transitioned to container | 1 |
| 2b→4d→3h | Ignited liquid, liquid or fumes released in area, fire transitioned to container | 1 |
| 2i→4d→3f | Upset or dropped container, liquid or fumes released in area, burned in place | 1 |
| 2i→4d→3e | Dropped or upset container, liquid or fumes released in area, exploded in place | 1 |
| 2d→4d→3j | Threw or kicked container, liquid released in area, direct container ignition | 3 |
| 2f→2i→4d→3e | Transported container, dropped container, liquid or fumes released in area, exploded in place | 1 |
| 2f→4d→3e | Transported container, liquid or fumes released in area, exploded in place | 1 |
| 2d→4d→3e | Threw or kicked container, liquid or fumes released in area, exploded in place | 1 |

TABLE VII CONTINUED

| Subsequence | Description | No. Cases |
|---|---|---|
| 4g→2a→4d→3e | Poured liquid in liquid transfer, liquid or fumes released in area, exploded in place | 3 |
| 4g→2a→4d→3f | Poured liquid in liquid transfer, liquid or fumes released in area, burned in place | 1 |
| 2g→4d→3h | Handled liquid, liquid or fumes released in area, fire transitioned to container | 5 |
| 2g→2i→4d→3f | Handled liquid, upset or dropped container, liquid or fumes released in area, burned in place | 1 |
| 2g→4d→3f | Handled liquid, liquid or fumes released in area, burned in place | 1 |
| 2g→4d→2b→3j | Handled liquid, liquid or fumes released in area, direct container ignition | 1 |
| 4h→2i→4d→3f | Liquid in storage, upset or dropped container, liquid or fumes released in area, burned in place | 1 |
| 2k→2i→4d→3f | Misidentified liquid, upset or dropped container, liquid or fumes released in area, burned in place | 2 |
| 2j→4h→4d→3h | Operator passive, liquid in storage, liquid or fumes released in area, fire transitioned to container | 3 |
| 2j→4d→3j | Operator passive, liquid or fumes released in area, direct ignition of container | 2 |
| 2d→4d→3h | Operator passive, liquid or fumes released in area, fire transitioned to container | 5 |

TABLE VIII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, PASSIVE

SPLASH, SPILL, LIQUID, FUMES, PREIGNITION, PERSON (4c) and AREA (4d)

| Subsequence | Description | No. Cases |
|---|---|---|
| $2a \to 2i \to \left\lvert\begin{smallmatrix}4e\\4d\end{smallmatrix}\right. \to 3g$ | Poured liquid, upset or dropped container, liquid and fumes released both on person and in area, fire transitioned to person | 1 |
| $2i \to \left\lvert\begin{smallmatrix}4e\\4d\end{smallmatrix}\right. \to 3i$ | Dropped or upset container, liquid and fumes released both on person and in area, direct person ignition | 3 |
| $2g \to 4c \to 4d \to 3h$ | Handled liquid, liquid spilled on person, liquid or fumes released in area, fire transitioned to container | 1 |
| $2g \to 4c \to 4d \to 3g$ | Handled liquid, liquid spilled on person, liquid or fumes released in area, fire transitioned to person | 1 |
| $2g \to 2i \to \left\lvert\begin{smallmatrix}4c\\4d\end{smallmatrix}\right. \to 3i$ | Handled liquid, dropped or upset container, liquid and fumes released both on person and in area, direct person ignition | 1 |
| $2f \to 2i \to \left\lvert\begin{smallmatrix}4c\\4d\end{smallmatrix}\right. \to 3f$ | Transported container, dropped container, liquid and fumes released both on person and in area, burned in place | 1 |
| $2f \to 2i \to \left\lvert\begin{smallmatrix}4c\\4d\end{smallmatrix}\right. \to 3i$ | Transported container, dropped container, liquid and fumes released both on person and in area, direct ignition person | 1 |
| $2f \to \left\lvert\begin{smallmatrix}4c\\4d\end{smallmatrix}\right. \to \left\lvert\begin{smallmatrix}3e\\3i\end{smallmatrix}\right.$ | Transported container, liquid and fumes released both on person and in area, exploded in place with direct ignition of person | 1 |

TABLE VIII CONTINUED

| Subsequence | Description | No. Cases |
|---|---|---|
| $2f \rightarrow \begin{matrix} 4c \\ \vert \\ 4d \end{matrix} \rightarrow 3g$ | Transported container, liquid and fumes released both on person and in area, fire transitioned to person | 1 |
| $2k \rightarrow 2f \rightarrow \begin{matrix} 4c \\ \vert \\ 4d \end{matrix} \rightarrow 3g$ | Misidentified liquid, transported container, liquid and fumes released both on person and in area, transitioned to person | 1 |

TABLE IX

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, PASSIVE

SPLASH, SPILL, LIQUID, FUMES--OTHER

| SUBSEQUENCE | DESCRIPTION | NO. CASES |
|---|---|---|
| 4h→2i→4j | Liquid stored in container, container upset, liquid released with no ignition or personal contact | 1 |

TABLE X

FUNCTIONAL FAILURE MODE SUBSEQUENCE--BARRIER

FIRE TRANSITION TO CONTAINER (3h)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2a→3h | Poured liquid, fire transitioned to container | 54 |
| 2a→4c→3h | Poured liquid, spilled liquid on person, fire transitioned to container | 1 |
| 2a→2c→3h | Poured liquid, startled, fire transitioned to container | 1 |
| 2b→3h | Ignited liquid, fire transitioned to container | 5 |
| 2i→3h | Dropped or upset container, fire transitioned to container | 1 |
| 4d→3h | Container released liquid or fumes to area, fire transitioned to container | 18 |

TABLE XI

FUNCTIONAL FAILURE MODE SUBSEQUENCE--BARRIER

DIRECT CONTAINER IGNITION (3j)

| Subsequence | Description | No. Cases |
| --- | --- | --- |
| 2a→3j | Poured fluid, container was directly ignited | 2 |
| 2b→3j | Ignited fluid, container was directly ignited | 17 |
| 2b→3i / 3j | Ignited fluid, container and person were directly ignited | 1 |
| 2d→3j | Threw or kicked container, container was directly ignited | 1 |
| 2g→3j | Handled fluid, container was directly ignited | 1 |
| 4d→3j | Container released fluid/fumes in area, container was directly ignited | 5 |

TABLE XII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, ACTIVE

SPLASH, SPILL--IGNITED (4e)

| Subsequence | Description | No. Cases |
|---|---|---|
| 3h→4e | Fire transition to container, ignited liquid spilled on person | 1 |
| 3h→4b→4e | Fire transitioned to container, burned in container, ignited liquid spilled on person | 4 |
| 3h→4b→2c→2d→4e | Fire transitioned to container, burned in container, startled, threw or kicked container, ignited liquid spilled on person | 1 |
| 3h→4b→2c→2i→4e | Fire transitioned to container, burned in container, startled, dropped or upset container, ignited liquid spilled on person | 1 |
| 3h→4b→2f→4e | Fire transitioned to container, burned in container, transported container, ignited liquid spilled on person | 1 |
| 3h→4b→2d→4e | Fire transitioned to container, burned in container, threw or kicked container, ignited liquid spilled on person | 8 |
| 3h→4b→4f→2d→4e | Fire transitioned to container, burned in container, container melted or burned, kicked or threw container, ignited liquid spilled on person | 2 |
| 3h→4b→2i→4e | Fire transitions to container, burned in container, upset or dropped container, ignited liquid spilled on person | 3 |
| 3h→4b→2c→4e | Fire transitioned to container, burned in container, startled, ignited liquid spilled on person | 6 |
| 3h→2d→4b→4e | Fire transitioned to container, threw or kicked container, burned in container, ignited liquid spilled on person | 1 |

TABLE XII CONTINUED

| Subsequence | Description | No. Cases |
|---|---|---|
| 3h→2c→2d→4e | Fire transitioned to container, startled, threw or kicked container, ignited liquid spilled on person | 2 |
| 3h→2d→4e | Fire transitioned to container, threw or kicked container, ignited liquid spilled on person | 5 |
| 3h→2c→4e | Fire transitioned to container, startled, ignited liquid spilled on person | 7 |
| 3j→4e | Direct ignition of container, ignited liquid spilled on person | 2 |
| 3j→4b | Direct ignition of container, burned in container, ignited liquid spilled on person | 1 |
| 3j→4b→2d→4e | Direct ignition of container, burned in container, threw or kicked container, ignited liquid spilled on person | 5 |
| 3j→4b→2i→4e | Direct ignition of container, burned in container, dropped or upset container, ignited liquid spilled on person | 7 |
| 3j→4b→2f→2i→4e | Direct ignition of container, burned in container, transported container, dropped container, ignited liquid spilled on person | 1 |
| 3h→ 4e \| 4f | Fire transitioned to container, container melted/burned and ignited liquid spilled on person | 1 |
| 3e→4e | Liquid exploded in place, ignited liquid splashed on person | 2 |
| 3e→4b→4e | Liquid exploded in place, burned in container, ignited liquid spilled on person | 2 |
| 3e→2c→4e | Liquid exploded in place, startled, ignited liquid spilled on person | 2 |

TABLE XII CONTINUED

| Subsequence | Description | No. Cases |
| --- | --- | --- |
| 3e→2d→4e | Liquid exploded in place, threw or kicked container, ignited liquid spilled on person | 1 |
| 3g→2c→4e | Fire transitioned to person, startled, ignited liquid spilled on person | 2 |
| 3f→4e | Liquid burned in place, ignited liquid spilled on person | 1 |
| 3f→4b→2i→4e | Liquid burned in place, burned in container, dropped or upset container, ignited liquid spilled on person | 2 |
| 3i \| 3j →4b→4e | Direct person and container ignition, liquid burned in container, ignited liquid spilled on person | 1 |

TABLE XIII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, ACTIVE

CONTAINER EXPLOSION (4a)

| Subsequence | Description | No. Cases |
|---|---|---|
| 3h→4a | Fire transitioned to container, container exploded | 36 |
| 3h→4a→2i | Fire transitioned to container, container exploded, dropped container | 1 |
| 3h→2i→4a | Fire transitioned to container, dropped container, container exploded | 1 |
| 3h→2c→4c→2i→4a | Fire transitioned to container, startled, spilled liquid on person, dropped container, container exploded | 1 |
| 3h→2d→4a | Fire transitioned to container, threw or kicked container, container exploded | 2 |
| 3j→4a | Direct ignition of container, container exploded | 5 |
| 3e→4a | Ignited liquid or fumes exploded in place, container exploded | 1 |
| 3e→2d→4a | Ignited liquid or fumes exploded in place, threw or kicked container, container exploded | 1 |

TABLE XIV

FUNCTIONAL FAILURE MODE SUBSEQUENCE--CONTAINMENT, ACTIVE

BURN IN CONTAINER ONLY (4b)

| Subsequence | Description | No. Cases |
|---|---|---|
| 3h→2i→4b | Fire transitioned to container, dropped or upset container, fire burned in container | 1 |
| 3h→4b→2f | Fire transitioned to container, burned in container, transported container | 1 |
| 3h→4b | Fire transitioned to container, burned in container | 3 |
| 3h→4b→2i→(4j) | Fire transitioned to container, burned in container, dropped or upset container (no burn, heart attack) | 1 |
| 3j→4b | Direct ignition of container, fire burned in container | 3 |

## TABLE XV

## FUNCTIONAL FAILURE MODE SUBSEQUENCE--HANDLING AND STABILITY

### UPSET OR DROP CONTAINER (2i)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2i→4c | Upset or dropped container, spilled or splashed liquid on person | 6 |
| 2i→4d | Upset or dropped container, spilled or splashed liquid in area | 2 |
| $2i \rightarrow \begin{matrix} 4c \\ \vert \\ 4d \end{matrix}$ | Upset or dropped container, spilled or splashed liquid on person and in area | 4 |
| 2i→4j | Upset or dropped container, container directly ignited | 1 |
| 2a→2i→4d | Poured liquid, upset or dropped container, spilled or splashed liquid in area | 1 |
| 2f→2i→4d | Transported container, upset or dropped container, splashed or spilled liquid in area | 1 |
| $2f \rightarrow 2i \rightarrow \begin{matrix} 4c \\ \vert \\ 4d \end{matrix}$ | Transported container, upset or dropped container, splashed or spilled liquid on self and in area | 2 |
| $2f \rightarrow 2i \rightarrow 4i \rightarrow \begin{matrix} 4c \\ \vert \\ 4d \end{matrix}$ | Transported container, upset or dropped container, container broke, liquid spilled or splashed on person and in area | 1 |
| 4b→2c→2i | Liquid burned in container, startled, upset or dropped container | 2 |
| 4b→2i→4e | Liquid burned in container, upset or dropped container, ignited liquid splashed or spilled on person | 7 |

TABLE XV CONTINUED

| Subsequence | Description | No. Cases |
|---|---|---|
| 4b→2f→2i→4e | Liquid burned in container, transported container, upset or dropped container, ignited liquid splashed or spilled on person | 1 |
| 2g→2i→4d | Handled liquid, upset or dropped container, splashed or spilled liquid in area | 1 |
| 4h→2i→4d | Stored liquid upset or dropped, splashed or spilled liquid in area | 1 |

TABLE XVI

FUNCTIONAL FAILURE MODE SUBSEQUENCE--IDENTIFICATION

MISIDENTIFY (2k)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2k→2g→2k→2a | Misidentified liquid, handled liquid, misidentified liquid, poured liquid | 1 |
| 2k→2f→ 4c / 4d | Misidentified liquid, transported container, splashed/spilled liquid on person and in area | 1 |
| 2k→2d→4d | Misidentified liquid, threw or kicked container, spilled liquid in area | 1 |

TABLE XVII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--STORAGE CONTROL

STORAGE (4h)

| Subsequence | Description | No. Cases |
|---|---|---|
| 2j→4h→4d | Operator passive, liquid stored in container, liquid or fumes released to area | 1 |
| 2j→4h→3e→4a | Operator passive, liquid stored in container, liquid exploded in place, container exploded* | 1 |

*Container left in hot sun and overheated

TABLE XVIII

FUNCTIONAL FAILURE MODE SUBSEQUENCE--STRUCTURAL INTEGRITY

CONTAINER FAILURE (4i)

| Subsequence | Description | No. Cases |
|---|---|---|
| 4i→2a→4c | Container failed, poured liquid, spilled or splashed liquid on person | 1 |
| 2f→2i→4i→ 4c \| 4d | Transported container, upset or dropped container, container failed, liquid released on person and on environment | 1 |
| 4b→4f | Fire burned in container, container melted/burned | 1 |

TABLE XIX

STANDARD APPLICATION TO FUNCTIONAL FAILURE MODE

| Functional Failure Mode | Standard and Paragraph | Comment |
| --- | --- | --- |
| Child Access Prevention | None | There are no specific requirements or recommendations for child proofing of containers, although some of the Structural Integrity and leak proofing requirements may prevent access to liquid. P 1674, par. 3.14 and 3.15 (identification and warning) may help in child training. |
| Dispensing | UL 30, Par. 2.6 2.11, 2.12 | Anti-spattering and valve operation are applicable to pouring stream configuration but not control and initiation of pouring except for automatic valve closing |
| | PS 6174, Par. 3.6 | A general pouring provision, only. |
| | Factory Mutual Par. 1.1 | Automatic valve closure provides a fast cut-off control. |
| | RR-S-30F Par. 3.4 | Automatic valve closure provides a fast cut-off control |
| Containment, Passive | UL 30 Par. 2.1, 2.5 2.7, 2.8, 2.10 PS 6174, Par. 3.4 | Containment capacity requirements will provide a space for expansion or splashing if containers are not over-filled. |
| | UL 30, Par. 2.6, 2.13 16.1, 18.1, 18.2 | Valve action and leakage requirements are specific to prevention of spillage. |
| | PS 6174, Par. 3.6, 4.6 | Spout leakage requirements are specific to liquid and, to some extent, fume release prevention. |
| | Factory Mutual Par.1.1 | Automatic valve closing provides a possible "deadman" cut-off for spout and other openings when container is not held by operator. |

TABLE XIX CONTINUED

| | | |
|---|---|---|
| | RR-S-30F Par. 3.4 | Automatic valve closing provides a possible "deadman" cut-off for spout and other openings when container is not held by operator. |
| | Other | Structural integrity requirements (see Structural Integrity) are generally relevant to Containment. |
| Barrier | UL 30, Par. 12.1, 12.2 | The screens or strainers might be adapted as a device to prevent flashback or direct ignition via the spout. |
| | UL 30 Par. 2.6, 2.13 16.1, 18.1, 18.2 | Valves may have some anti-flashback valve. |
| | PS 6174 None | |
| | Factory Mutual Par. 2.3, 3.4, 3.5 | The flame arrester requirements would seem to provide for a specific barrier function at spout openings. The barrier implications of the flame exposure test are not clear. |
| | RR-S-30F Par.3.5.1, 3.5.4, 3.5.5, 4.4.1, 4.4.7 | The flame arrester requirements would seem to provide for a specific barrier function at spout openings. The flame exposure test implies rather rigorous structural barrier requirements. |
| Containment, Active Splash, Spill, Ignited | See Containment, Passive | The provisions which prevent unintended release of unignited liquid may also reduce the release of ignited fluid. |
| Containment, Active Explosion | UL 30, Par. 2.14 Otherwise None<br>PS 6174 None | The UL 30 pressure release provision may reduce the magnitude of an explosion during initial buildup but this effort would not be extensive. |
| Containment, Burn in | UL 30, See Structural Integrity | Structural integrity provisions are generally applicable |

TABLE XIX CONTINUED

| | | |
|---|---|---|
| | PS 6174, See Structural Integrity | Structural integrity provisions are generally applicable. However, paragraphs 3.2.3, 3.12, and 3.14 state that plastic jerry cans are flammable. |
| Handling and Stability | UL 30, Par. 10.1, 10.2, 10.3 | Handle placement and dimensions |
| | PS 6174, Par. 3.7 | Specifies only that a handle shall be provided. |
| | UL 30, Par. 2.4, 15.1 | Specifies base diameter to height ratio for stability and provides for stability testing on an inclined surface |
| | PS 6174, Par. 3.5 | Stability testing on an inclined surface. |
| | Factory Mutual Par. 3.1 | Provides for a can tilt and drop-back test |
| | RR-S-30F Par. 3.5.3, 4.4.3 | The requirements are unclear. The performance requirement seems to imply an inclined surface test but the test requirement is for a can tilt and drop-back test. |
| Identification | UL 30 None | |
| | PS 6174, Par. 3.14, 3.15 | Recommends red as a color and refers to Federal Hazardous Substances Act |
| Storage Control | UL 30, Par. 2.14 Also see Structural Integrity | Pressure release provision is relevant and Structural Integrity provisions are generally relevant. |
| | PS 6174 | Structural integrity provisions are generally relevant. |

TABLE XIX CONTINUED

| | | |
|---|---|---|
| Structural Integrity | UL 30, see Appendix 2, Table I, Structural Integrity paragraphs | The UL 30 standard has extensive coverage on Structural provisions. |
| | PS 6174, see Appendix 2, Table I, Structural Integrity paragraphs | The PS 6174 standard is not quite as extensive in coverage as UL 30 but has provisions specific to plastic containers. |

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5. Standards for Safety, Metal Safety Cans, Underwriters Laboratories, Inc., UL 30, Approved as ANSI Z218.1-1971, March 9, 1971

6. Plastic Containers (Jerry Cans) for Petroleum Products, Voluntary Product Standard 6174, May 1, 1974.

7. Approval Standard, Safety Containers and Filling, Supply and Disposal Containers, Factory Mutual Research, Class 6051 and 6052, May 1976.

8. Safety Cans, Spring Closing Type, Federal Specification RR-S-30F, April 18, 1975.

## APPENDIX 1

## ACCIDENT EVENT CODING

The following coding system was developed and utilized during the analysis of the IDIR's and FFACT accident reports in this study. While all of the coding items were considered in the accident event analyses and sequences, some of the items were not included in tabulating the functional failure mode subsequences since they did not appear to provide significant information concerning the functional failure mode. These omissions are indicated by an asterisk(*) in the following list.

| Code | Title | Description |
|---|---|---|
| 1 | Type of Container | The container utilized by the operator to pour, carry, etc. the liquid. |
| 1a | Standard gasoline or kerosene | The type of container usually sold in retail stores as a gasoline or kerosene can. |
| 1b | Spout can - metal | A container with an enclosed pouring spout and constructed of material as noted, but not identifiable as 1a. |
| 1c | Spout can - glass | |
| 1d | Spout can - plastic | |
| 1e | Spout can - unknown | |
| 1f | Small mouth jar or can - metal | A container with a relatively large capacity body and a small top opening for filling and dispensing, e.g., a plastic milk jug, constructed of material as noted. |
| 1g | Small mouth jar or can - glass | |
| 1h | Small mouth jar or can - plastic, cardboard, paper | |
| 1i | Small mouth jar or can - unknown | |
| 1j | Bottle | A container with a standard bottle configuration, e.g., a soft drink bottle. |
| 1k | Open top, deep - metal | A container in a wide mouth, open top configuration constructed of material as noted, e.g., a drinking glass, tin can, pail. |
| 1l | Open top, deep - glass ceramic | |
| 1m | Open top, deep - plastic, paper cardboard | |

| | | |
|---|---|---|
| 1n | Open top, deep - unknown | |
| 1o | Open top, shallow - metal | A container in a pan or semi tray configuration constructed of material as noted, e.g., a paint roller tray. |
| 1p | Open top, shallow - glass, ceramic | |
| 1q | Open top, shallow - plastic | |
| 1r | Open top, shallow - unknown | |
| 1s | Unknown | Unidentifiable from the report. |
| 2 | User Operation | The activity carried out with or on the container and liquid by the user of the liquid, i.e., the operator. |
| 2a | Pour or Spray - | Transmit the liquid from the can intentionally |
| 2b | Ignite | Directly apply flame to the liquid, either in the container or elsewhere |
| 2c | Startle | Jump back or otherwise move suddenly with more or less the whole body. |
| 2d | Throw or kick away | Propel the container through the air other than by knocking it over or off of a support. |
| 2e | Ingest | Drink or aspirate liquid |
| 2e1 | Ingest, spill | Spill liquid from container and ingest |
| 2e2 | Ingest from container | Drink directly from container |
| 2e3 | Container transfer | Transfer liquid to a second container and drink from second container |
| 2e4 | Open container | Open container to ingest liquid |

| | | |
|---|---|---|
| 2f | Transport | Move the container from one place to another or passively hold container. |
| 2g | Handle liquid | Deliberately contact liquid with some part of person, e.g., cleaning with liquid |
| 2h | Siphon | Transfer liquid from a container by hose and suction method |
| 2i | Upset or drop container | Overturn container or accidentally let it fall |
| 2j | Passive | Not actively using or interfacing with container or liquid |
| 2k | Misidentify | Mistake liquid for something other than what it is because of nature of container or circumstances. |
| 3 | Fire action mode | The interface with the fire by liquid, container or person. |
| *3a | Liquid interface | Interface with fire by liquid directly |
| *3b | Fume interface | Interface with fire by fumes only or primarily |
| *3c | Fire to liquid or fumes | Fire applied to liquid, e.g., a spark into container |
| *3d | Liquid or fumes to fire | Liquid or fumes applied to fire, e.g., pouring liquid onto coals |
| 3e | Explode in place | A localized explosion which is not generalized or in the container |
| 3f | Burn in place, only | A localized "puddle" fire |
| 3g | Transition to person | Ignition of person through a flashback along a stream of liquid/fumes |
| 3h | Transition to container | Ignition in container through a flashback along a stream of liquid/fumes. |
| 3i | Direct person ignition | Direct ignition of person, e.g., from previously spilled gas on person ignited by a spark |

| | | |
|---|---|---|
| 3j | Direct container ignition | Direct ignition of liquid/fumes in container, e.g., from a spark entering a container. |
| 4 | Container involvement mode | The direct participation in or interface of a container with accident events |
| 4a | Explode | Explosion of the container from ignition of liquid/fumes within container. Usually includes 4e. |
| 4b | Burn in | Ignition and burning of liquid in container but without an identifiable explosion |
| 4c | Splash/Spill, pre-ignition, person | Release non-ignited fluid from container to person |
| 4d | Splash/Spill, pre-ignition, area | Release of unignited liquid or fumes to area |
| 4e | Splash/Spill-Ignited or in ignition process | Release of flaming liquid, or immediately ignited liquid, to person or area, also included in 4a. |
| 4f | Melt/burn | Ignition of material of container |
| 4g | Liquid access/ transfer | The role of the configuration or structure of the container in permitting access to liquid or influencing transfer of liquid from one container to another. |
| 4h | Storage | The characteristics of a container as a holding facility for liquid. |
| 4i | Container failure | Structural or material failure of the container |
| 4j | Splash/Spill, no ignition | Release of liquid to person or area with no subsequent ignition |
| 5 | Injury mode | Immediate source of injury to victim from accident |
| *5a | Explosion - direct | Injury from direct effects of an explosion |

| | | |
|---|---|---|
| *5b | Burn - direct | Injury from direct contact with a fire |
| *5c | Burning fluid | Injury from burning liquid splashed or spilled on person |
| *5d | Fluid on person ignited | Injury resulting from ignition of liquid splashed or spilled on person prior to ignition |
| *5e | Container burn | Injury from contact with a hot, melting or burning container |
| *5f | Ingestion - direct | Injury from drinking or aspirating spilled liquid or liquid from a container |
| *5g | Ingestion - siphon | Injury from ingestion or aspiration of liquid from a siphoning hose |
| *5h | Liquid contact | Injury from skin contact with liquid |
| *5i | Other | Injury other than above, e.g., a heart attack precipitated by reaction to an explosion |
| *5j | None apparent | No further injury identified from the accident report |

## APPENDIX 2

## STANDARDS SUMMARY

The basic definitions of flammable and combustible liquids and containers for this study are contained in the Flammable and Combustible Liquids Code, NFPA No. 30-1976. Flammable and combustible liquids are defined as follows:

> Flammable Liquid shall mean a liquid having a flash point below 100° F (37.8° C) and having a vapor pressure not exceeding 40 pounds per square inch (absolute) at 100° F (37.8° C) and shall be known as a Class I liquid.
>
> Class I liquids shall be subdivided as follows:
>
> Class IA shall include those having flash points below 73° F (22.8° C) and having a boiling point below 100° F (37.8° C).
>
> Class IB shall include those having flash points below 73° F (22.8° C) and having a boiling point at or above 100° F (37.8° C).
>
> Class IC shall include those having flash points at or above 73° F (22.8° C) and below 100° F (37.8° C).
>
> Combustible Liquid shall mean a liquid having a flash point at or above 100° F (37.8° C).
>
> Combustible Liquids shall be subdivided as follows:
>
> Class II liquids shall include those having flash points at or above 100° F (37.8° C) and below 140° F (60° C).
>
> Class IIIA liquids shall include those having flash points at or above 140° F (60° C) and below 200° F (93.4° C).
>
> Class IIIB liquids shall include those having flash points at or above 200° F (93.4° C).

Safety Can is defined as follows:

> Safety Can shall mean an approved container, of not more than five gallons capacity, having a spring-closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure.

The citation of this definition does not necessarily indicate that the gasoline and kerosene containers to be standardized for home use must correspond to this definition in all particulars.

The standards available for this study are UL-30, Standard for Safety, Metal Safety Cans; PS 61-74, Voluntary Product Standard for Plastic Containers (Jerry Cans) for Petroleum Products; and the Factory Mutual Research Approval Standard for Safety Containers and Filling Supply and Disposal Containers. The RR-S-30F Federal Specification for Safety Can, Spring Closing Type is also cited. The provisions of these documents are summarized in Table I of this Appendix.

TABLE I

STANDARDS SUMMARY

| Std. | Subject | Paragraph | Summary |
|---|---|---|---|
| UL-30 | Scope | 1.1<br>1.2<br>1.3<br>1.4 | Metal Safety cans for the storage and handling of small quantities of flammable liquids. Covers Type I cans, 4 pints to 5 gallons with a short valved spout for both pouring and filling, and Type II cans, 1 gallon to 5 gallons with a valved spout equipped with a flexible or tubular nozzle for pouring only. |
| PS 6174 | Scope | 2 | Plastic container (jerry cans) of up to 7 gallons for the temporary storage of petroleum products. |
| Factory Mutual | Scope | 1.1 | Safety Containers and filling, supply or disposal containers for flammable liquids, up to five gallon capacity. |
| RR-S-30F | Scope | 1.1 | Safety Cans of the spring closing type for temporary storage or handling of flammable liquids. |
| UL-30 | Containment Capacity | 2.1<br>2.5<br>2.7<br>2.8<br>2.10 | Each can shall have sufficient capacity for its designated size with all openings above the highest normal liquid level. Cans less than 1 quart shall be limited to one valved opening for both filling and pouring. Cans greater than 1 quart shall have no more than two valved openings adapted to pouring and filling. Use of funnels during filling shall not interfere with venting of can. |
| | Containment, valve action, possible barrier to ignition | 2.6<br>2.13 | Each opening shall have valves which will remain securely closed with the can in any position until it is opened manually. |

TABLE I CONTINUED

| | | | |
|---|---|---|---|
| | Containment, valve testing, possible barrier to ignition | 16.1<br>18.1<br>18.2 | Valves or closure shall not show a greater than specified leak when inverted. Valves shall not open when can is laid on its side on a plain surface. Valves and closures shall withstand 10,000 operations without failure or leakage. |
| PS 6174 | Containment, capacity | 3.4 | Full capacity shall exceed nominal capacity |
| | Containment, Pouring closure | 3.6<br>4.6 | Pouring closure shall not leak |
| | Containment, permeability | 4.10 | Filled container shall be weighed after 30 day storage |
| Factory Mutual | Containment, Valve Action and Caps | 1.1 | Containers are tightly fitted with valves or caps that remain closed unless held open for filling or discharging liquid. |
| RR-S-30F | Containment, Valve Action | 3.4 | Openings shall have independent, automatic closing valves designed to remain closed with the can in any position until automatically opened. |
| UL-30 | Pressure relief, possible anti-explosion measure | 2.14 | Internal pressure in excess of 5 psi shall be relieved by a pressure release device. |
| UL-30 | Possible barrier to ignition | 12.1<br>12.2 | Screens or strainers shall be of perforated brass or other corrosion resistant material and shall be, if used, removable for cleaning. |
| Factory Mutual | Ignition Barrier | 2.3<br>3.4<br>3.5 | All openings for handling non-viscous liquids shall be protected by a flame arrester. Natural gas shall be passed through the flame arrester and ignited to burn on the flame screen; no flame shall pass through the flame arrester. The container filled with flammable liquid shall be placed in an ignited liquid and the contents of the can shall be retained without rupture or spillage. |

TABLE I CONTINUED

| | | | |
|---|---|---|---|
| RR-S-30F | Ignition Barrier | 3.5.1<br>3.5.4<br>3.5.5<br>4.4.1<br>4.4.7 | The flame arrester shall prevent the flame of a hydro carbon gas-air mixture from reaching the gas source by passing through the flame arrester. The can filled with gas shall be placed in burning gasoline without leakage of contents or burning within the can. |
| UL-30 | Dispensing | 2.6<br>2.11<br>2.12 | Pouring spouts shall be formed so that liquid will pour without excessive spattering. Type II cans shall incorporate a vent valve to open and close in coordination with the pouring valve. |
| PS 6174 | Dispensing | 3.6 | Container shall be provided with an integral or add-on pouring nozzle which shall not leak when liquid is poured. |
| UL-30 | Stability | 2.4<br>15.1 | Diameter of base of can shall be not less than 85% of the height of the body. Stability shall be retained when a filled can is placed on an inclined plane forming an angle of 30 degrees with the horizontal. |
| PS 6174 | Stability | 3.5 | Shall not upset when placed filled on an inclined plane of 20 degrees. |
| Factory Mutual | Stability | 3.1 | When tipped to an angle of 30 degrees from the horizontal and released the filled container shall return to the upright position. |
| RR-S-30F | Stability | 3.5.3<br>4.4.3 | The can shall not tip when one edge is inclined 30 degrees from the horizontal as specified in 4.4.3. When tipped to an angle of 30 degrees from the horizontal and released the filled container shall return to the upright position. |

TABLE I CONTINUED

| | | | |
|---|---|---|---|
| UL-30 | Handling | 10.1<br>10.2<br>10.3 | The can shall be provided with a handle with a comfortable handgrip, of dimensions specified in 10.3, and grasping provision on the bottom of the can for pouring. |
| PS 6174 | Handling | 3.7 | A handle shall be provided for carrying the filled container. |
| UL-30 | Identification and warning | None | |
| PS 6174 | Identification and warning | 3.14<br>3.15 | The preferred color is red. Container shall be labeled in accordance with Federal Hazardous Substances Act and State and Local Regulations. |
| UL-30 | Structural integrity - general | 2.2<br>2.3 | Safety cans shall be free from defects which may impair their appearance, serviceability and safety and shall be constructed of commercial grade materials |
| | Structural integrity - leakage | 2.15<br>7.5<br>11.1<br>13.1 - 13.6<br>17.1<br>21.1 - 21.5<br>22.1 | Leak proofing of nozzles and fittings leak tests and strength tests including manufacturing and production tests |
| | Structural integrity - construction | 3.1 - 3.4<br>4.1 - 4.2<br>5.1 - 5.2<br>6.1 - 6.3<br>7.1 - 7.4<br>8.1 - 8.8<br>13.1 - 13.6 | Construction and materials standards for top, bottom, body; seams and joints; support ring; pouring spouts and fill fittings, pouring nozzles; valve and valve operating mechanisms; and protective coatings. |

TABLE I CONTINUED

| | | | |
|---|---|---|---|
| PS 6174 | Structural integrity - flammability | 3.2.3<br>3.12<br>4.12 | Standards for burning rate and for flammability resistance as a factor in leakage. |
| | Structural integrity - temperature | 3.2.1<br>3.2.2 | Standards for high temperature (Vicat softening point) and low temperature (brittleness temperature) structural resistance. |
| | Structural integrity - strength | 3.8<br>3.9<br>4.7<br>4.8<br>4.9 | Construction and material standards and tests for drop strength, hydrostatic pressure, and handle strength. |

## APPENDIX 3

### FUNCTIONAL FAILURE

The following scenarios illustrate accident event sequences for eight functional failure modes:

1. Child Access Prevention - Ingestion

Sequence $4g \to 2k \to 2e2 \to 5f$

The subject's father had used gasoline in a plastic measuring cup to start a lawn mower. When he succeeded in starting the mower, he proceded to mow the lawn in the rear of the house, leaving the cup about half filled with gasoline on the steps of the back porch. His three year old son came out of the house, drank the gasoline and began to choke and cry. The father took the child immediately to the emergency room of the local hospital. The child was treated for digestive upset and kept in the hospital for observation to determine if any gasoline had entered the lungs.

2. Child Access Prevention - Burn

Sequence $4g \to 2a \to 2g \to \left|\begin{matrix}3b\\3d\end{matrix}\right. \to \left|\begin{matrix}3h\\3i\end{matrix}\right. \to 4b \to \left|\begin{matrix}5b\\5d\end{matrix}\right.$

The four year old child was playing in the basement of the home. He found a five gallon glass jug about three quarters full of gasoline which his older brother kept for his mini bike. The child poured the gasoline in an old pan and started to wash a small toy. The gasoline ignited from the pilot light of a hot water heater. The gasoline ignited in the pan and on the child's hands and arms. The child's mother heard the child screaming, ran into the basement and smothered the flames on the child with a nearby throw rug. The child was taken to a burn unit at the __________ hospital. The child received severe burns on his hands and both arms with less severe burns on his neck and face.

3. Dispensing

Sequence $2a \to 4c \to 2b \to \left|\begin{matrix}3a\\3c\end{matrix}\right. \to 3g \to 5d$

The subject poured gasoline on a barbeque from a five gallon gasoline can. He poured gasoline on his trousers. He set the can aside and dropped a lighted match on the barbeque. The barbeque flared up and his pants ignited. He hastily removed his pants. He then drove to a local hospital where he was treated for moderate burns on his legs.

4. Containment, Passive

Sequence $2a \to 2c \to 4c \to \begin{matrix} 3a \\ | \\ 3c \end{matrix} \to 3g \to 5d$

The subject poured gasoline on a smouldering pile of leaves from a coffee can. The leaves flared up and the man jumped back suddenly and spilled the gasoline on his trousers. The gasoline caught fire on his clothes. The man rolled on the ground to extinguish the fire. His wife drove him to the burn unit at ________ hospital where he was treated for burns on his upper legs.

5. Barrier and Containment, Active

Sequence $2a \to \begin{matrix} 3a \\ | \\ 3d \end{matrix} \to 3h \to 4a \to \begin{matrix} 5a \\ | \\ 5c \end{matrix}$

The subject poured gasoline from a five gallon gasoline can on a smouldering barbeque. The fire flashed back up the stream of gas and the container exploded. The man was splashed with flaming gasoline. He was rolled on the ground by his wife and brother to extinguish the flames. He was taken to a burn unit at ________ hospital. He was hospitalized for severe burns on his upper body and chest.

6. Handling and Stability

Sequence $2f \to 2i \to 4d \to \begin{matrix} 3b \\ | \\ 3d \end{matrix} \to 3f \to 5b$

The subject went to the basement to obtain a five gallon can of gasoline. He was carrying the can by the handle when it slipped from his hand and overturned. When it hit the floor, the gasoline spilled from the spout of the can and was ignited on the floor by the pilot light of a hot water heater. The pool of gasoline flared up and the flame burned the subject. The subject drove to the office of his family physician where he was treated for moderate burns around his ankles and lower legs.

7. Identification

Sequence $2k \rightarrow 2a \rightarrow \begin{matrix} 3a \\ | \\ 3d \end{matrix} \rightarrow 3f \rightarrow 5b$

The subject's husband had used a small pail of gasoline to start a trash fire. He left the pail, with some gasoline in it, sitting on the ground about 200 feet from the fire and near an outdoor faucet while he went for more trash. The subject came out of the house and noticed that the fire was spreading toward some dry grass. She assumed the pail contained water and poured the gasoline from it on the edge of the fire. The gasoline flared up and ignited her skirt. She quickly removed her skirt but not before she had received slight to moderate burns around one leg.

8. Storage and Structural Integrity*

Sequence $2j \rightarrow 4h \rightarrow 4j \rightarrow 5j$

The subject* purchased a two gallon gasoline can on June 20, 1977 at an auto supply store. The can was of steel construction and had a steel spout which was stored inside the can by screwing the base of the spout into the filling/pouring outlet. When in the stored position a second cap screwed inside the base of the spout to form a cap for the otherwise open outlet. A small plastic "flip to vent" cap was installed in the top of the can in the corner opposite to the spout. There was a removable cork seal in the screw base of the spout assembly covering the spout opening. The container was stored about three-fourths full of gasoline in a garage during the hot weather of July 1977. During the week of July 27, the subject's wife noticed that the top of the container was covered with gasoline and the hollow, cup-like top of the screw top over the spout base was filled with gasoline. Upon examination, initially by the subject and later by the present writer, the container was found to be structurally intact. The subject states that vapor pressure above the gasoline in the can had forced gasoline up through the stored spout. The gasoline penetrated the cork seal and leaked through the screw cap above the spout opening to collect on top

*This scenario was provided by Dr. R.J. Lepkowski, Office of Energy Related Inventions, Institute for Applied Technology, National Bureau of Standards, Washington, D.C.

of the can and in the top of the screw cap. The subject states that no gasoline was found to have been released through the "flip to vent" cap. It should be noted that the subject is anosmic (defective sense of smell) and frequently smokes a pipe. He, therefore, could have entered into a potential gasoline explosion situation with no warning.

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| | 14. Sponsoring Agency Code |

15. SUPPLEMENTARY NOTES

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

Accidents involving home use of gasoline and other flammable and combustible liquid containers were analyzed to define the functions a safe container should perform and how the containers failed to perform these functions. Safety standards were evaluated for applicability to these functional failures. The standards were considered inadequate to prevent child access to fluids in the containers, somewhat adequate for fluid management and isolation from ignition sources and very adequate for container structure and materials.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Children; containers; failure analysis; flammable fluids; gasoline; hazards; kerosene; safety; standards

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